UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 872

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. November 11, 1920

INSECT CONTROL IN FLOUR MILLS

By

E. A. BACK, Entomologist in Charge of Stored-Product Insect Investigations

CONTENTS

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CONTENTS.

MILL INSECT CONDITIONS BETTERED.

The control of insect pests in flour and cereal mills has become a very important feature of food conservation and of mill construction and operation. The cleanliness of many of the well-lighted, concrete mills, such as are being built more frequently now than ever before, and their comparative freedom from pests, are emphasized by the conditions that exist in old-type structures. These latter offer insects every advantage in their fight against the miller. It is true that many of these older mills are established in rambling, loosely constructed buildings that can be neither properly cleaned, from the standpoint of insect destruction, nor made tight for the application of successful control measures. Fortunately the losses caused by insects to the mill owners and the advantages of modern construction are working hand in hand to bring about a constant change for the better. With modern equipment installed in buildings erected with a view to suppressing insects, more millers are joining the ranks of those who know that they can control insects and offer the public a product reasonably free from infestation.

INCENTIVE LEADING TO INSECT SANITATION.

Owners of flour mills are frequently blamed by brokers, retail grocers, and the public at large for insect infestations found in their products when these appear on the market or in the home. Sometimes the miller is to blame; often he is not. It is, however, within his

power, if he is the owner of a well-constructed mill, so to control pests that he can state, with honesty, that the product he places upon the market is reasonably free from insects, including their eggs, and that if infestation develops soon after his product has been warehoused or otherwise disposed of, the infestation is due to one or more of several known conditions for which he is in no way responsible.

There has persisted among many millers, as well as consumers, the belief that the egg or "germ" of insects is within the grain at the time it enters the mill and that it goes uninjured through the milling process to lie dormant in the finished product until such time as conditions of warmth and moisture favor its development. This belief rests upon a false foundation. The ordinary destructive insects that infest grain or flour or any cereal product lay eggs large enough to be readily seen by an experienced eye once they are separated from the host material. They are all so large that they can not pass through the meshes of No. 10 XX silk bolting cloth. Since this is true, even badly infested flour can be reprocessed and rendered absolutely free from pests if bolted through a No. 10 XX or finer cloth.

It is possible to produce flour entirely free from infestation as it comes from the bolting machines. If it is sacked in containers upon which no eggs have been laid or in which no larvæ are present, and is stored in a warehouse in which there is no infestation, it will leave the mill free of infestation. If such a product shows infestation by the time it reaches its destination, it has become infested while en route. To guarantee a product leaving the mill establishment as free from infestation is so entirely within the bounds of reason that one wonders whether certain millers should be permitted to ignore insect infestations and put upon the market supplies that are invariably infested.

MEDITERRANEAN FLOUR MOTH.[1]

MEDITERRANEAN FLOUR MOTH MOST SERIOUS MILL PEST.

While there are many insects that may become troublesome in flour mills, it is the Mediterranean flour moth alone that seriously affects the operation of the mill and has brought with its advent from Europe into the mills of the United States losses that have forced millers to consider insect suppression. The weevils and other granary pests which are brought into mills with grain, and the flour beetles or "bran bugs" which become established in practically all mills sooner or later, will not be discussed in this bulletin, though they must be taken into consideration by millers. The remedial measures advocated for the suppression of the Mediterranean flour moth, with cleanliness, will hold these nonwebbing insects in check.

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[1] *Ephestia kuehniella* Zell.

MEDITERRANEAN FLOUR MOTH AN INTRODUCED PEST.

The Mediterraneon flour moth is a pest introduced into this country from Europe. Until 1877 it was little known in the Old World, but in that year it was discovered in a flour mill in Germany. Later it spread to Belgium and Holland, and in 1886 was found in England. In 1889 it was found in destructive numbers in Canada. The Mediterranean flour moth first appeared in the United States in 1892, when it was found infesting flour mills in California. Since that time its spread has been fairly rapid. It was found established in New York and Pennsylvania in 1895, in Minnesota in 1898, in Wisconsin in 1900, and in Michigan in 1902. By 1904 it was reported from other States, including Indiana, Illinois, Montana, Colorado, Ohio, and Iowa. Since 1904 its spread has been very rapid, until at the present time the Mediterranean flour moth is present in practically every milling center and may be found in warehouses throughout the country where flour and cereal products are stored.

LOSSES DUE TO INFESTATION.

Millers have reason to dread this pest, since the webbing habit or the larvæ sometimes completely stops the machinery and always, sooner or later, necessitates the expenditure of time and money to keep the pest under control. It is difficult to obtain definite estimates of losses caused by the Mediterranean flour moth, but for mills of 1,000 barrels capacity it is seldom less than $100 to $200 a year. The average loss, according to Dr. F. H. Chittenden, "due to closing down the mill and cost of treatment seems to be not far from $500 for each fumigation, 'to say nothing of the loss to business,' according to one Kansas milling firm. An estimate of $1,000 for two fumigations would not be far from right, although others estimate $2,000, and still others—owners of larger mills—claim it to be $5,000 a year." Prof. G. A. Dean has stated that the loss to Kansas grain and mill interests may be placed very reasonably at "not less than $2,000,000 annually." It is evident that the loss to flour and cereal mill owners throughout the country is enormous and far beyond the average belief.

TRANSFORMATIONS OF THE MEDITERRANEAN FLOUR MOTH.

The adults of the Mediterranean flour moth are moths or millers with a winged expanse of a little less than 1 inch. The forewings are pale leaden gray with black markings, as shown in figures 1 and 2, although sometimes the wings are much darker. These parent moths are very tame, and when resting quietly upon various portions of the mill and stocks assume a peculiar attitude, illustrated

in figures 1, *b*, and 2. The female moth lays eggs in accumulations of flour, up and down elevator legs, throughout spouts, around dust collectors, in bolters, purifiers, etc. From these eggs hatch the larvæ or worms. When full grown, the larvæ are about half an inch long and are whitish or pinkish in color, with minute black dots and fine hairs, as shown in figure 1, *c*, *e*. When full grown the larvæ spin cocoons in which they transform into the reddish brown pupæ shown in figure 1, *d*. From these pupæ emerge the parent moths of the next generation.

LENGTH OF LIFE FROM EGG TO ADULT.

Dean [2] states that when the temperature ranges from 85° to 90° F., the eggs of the moth hatch in about 3 days, the larvæ become full grown in about 40 days, and the pupal stage requires from 8 to 12 days more. Under ordinary flour-mill conditions about 9 weeks are required for the pest to pass through its life cycle from egg to adult. Length of the life cycle varies greatly with the temperature. At temperatures lower than 55° F. activity is suspended. During most favorable temperature conditions, 24 days has been found by Chittenden [3] to be the minimum required for larval development.

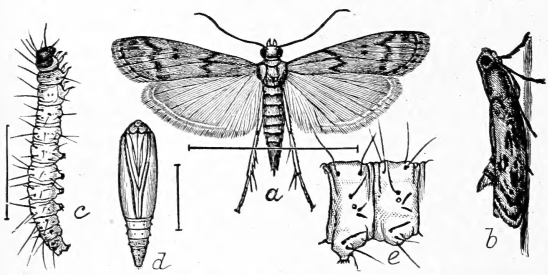

FIG. 1.—Mediterranean flour moth: *a*, Moth; *b*, same from side, resting; *c*, larva; *d*, pupa; *e*, abdominal segments of larva. The hair lines by *a*, *c*, and *d* represent the actual length of the forms. (Chittenden.)

LARVAL HABITS MAKE MOTH MOST SERIOUS PEST.

The Mediterranean flour moth is the most serious of all mill pests, not so much because of the food values it actually consumes, but because the larvæ or worms construct in the flour silken tubes in which they live, spin a fine silken thread wherever they crawl, and spin cocoons in and about the machinery and stock. As they grow older they spin increasing amounts of silk until, when they are full grown, the quantity of web they spin in crawling about machinery, sacks, etc., in search of a suitable place to spin cocoons is enormous, and causes a bad webbing or matting of the flour. These masses of webbed flour receive during the operation of the mill fresh layers of flour, which

[2] DEAN, G. A., MILL AND STORED-GRAIN INSECTS. Kans. State Agr. Coll. Exp. Sta. Bul. 189, p. 226–227. July, 1913.

[3] CHITTENDEN, F. H., THE DEVELOPMENT OF THE MEDITERRANEAN FLOUR MOTH. *In* U. S. Dept. Agr. Div. Ent. Bul. 6 (n. s.), p. 85–88, 1896.

in turn are matted together by the burrowing and crawling larvæ. Finally the webbed masses (fig. 3) become so large that they choke or clog the machinery and force the miller to shut down. There is then nothing left for the miller to do but set his men to a thorough cleaning out of all machinery, spouts, etc.

HOW MILLS BECOME INFESTED.

The Mediterranean flour moth gains access to the majority of mills through the medium of secondhand or returned sacks. The moths occur in blending plants, where they lay eggs on old sacks, and the lar-

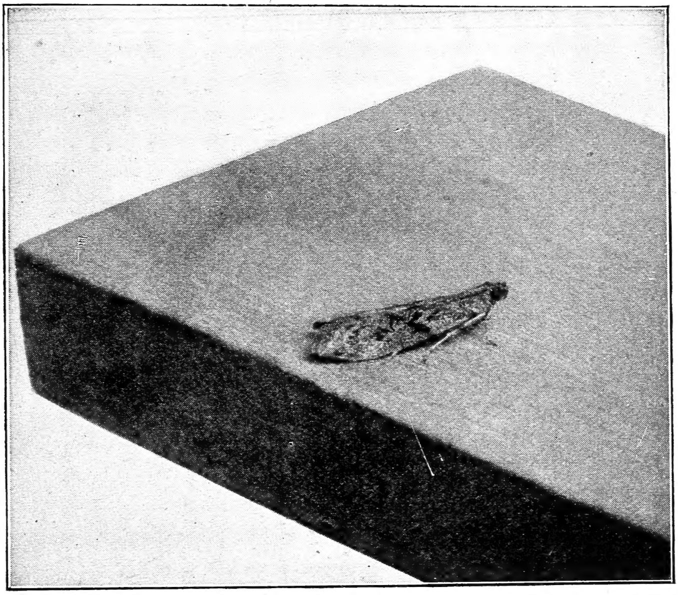

FIG. 2.—An adult Mediterranean flour moth resting naturally upon a plank. Notice characteristic posture. These moths are so tame and remain so quiet that they often escape attention. (Dean.)

væ then hide and spin cocoons in the seams and folds, thus making it easy for the pest to be carried from place to place. The installing of secondhand machinery that has not been properly fumigated is also a means of dissemination. These are the main avenues of entry to uninfested and new mills that any miller can close if he will. The miller is, however, more or less helpless to prevent infestations when his mill is located in a center of general infestation, as the adult moth can fly from building to building. Of course, all returned sacks are apt to bring infestations.

WHERE TO LOOK FOR EARLY INFESTATIONS.

Millers who fear that the Mediterranean flour moth will become established in their mills and wish to apply remedial measures as

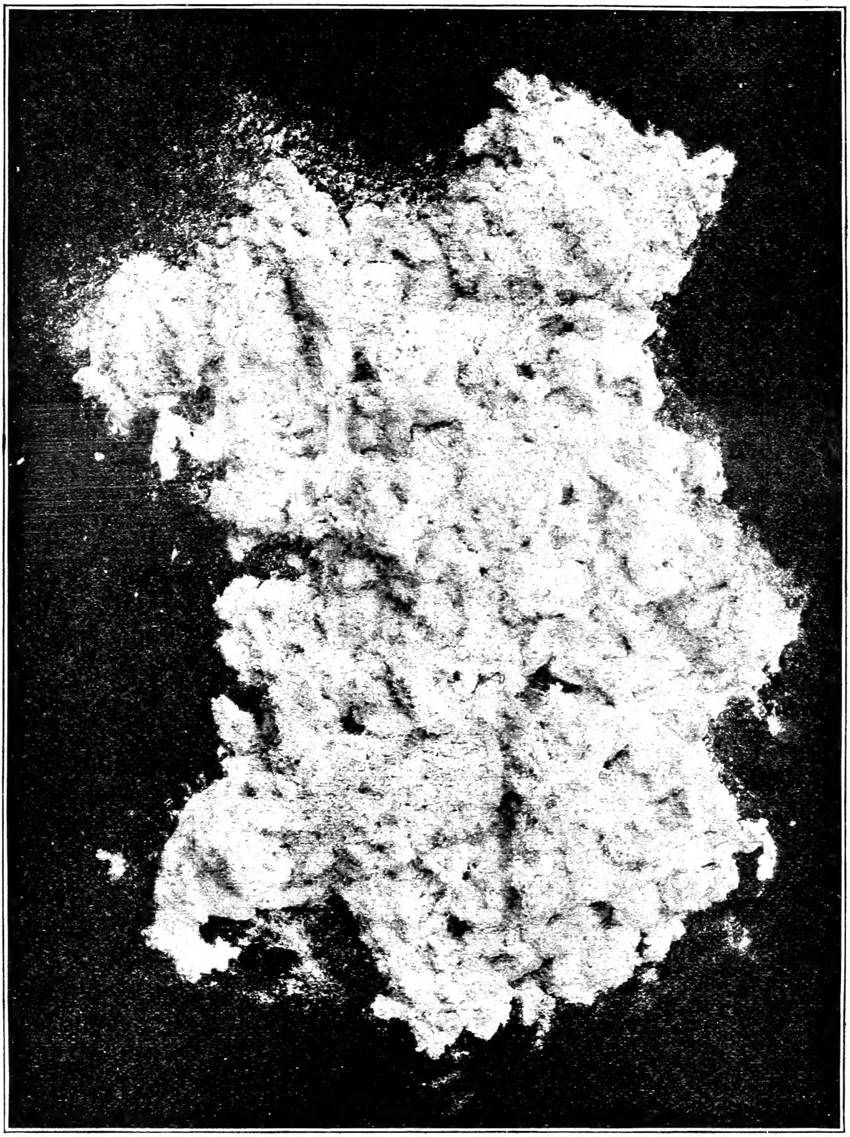

FIG. 3.—A clump of matted flour showing result of the webbing habit of the larvæ of the Mediterranean flour moth. (Chittenden.)

early as possible should keep an especially close watch for the pest in places where it is apt to appear first. These are in elevators, purifiers, and the machinery carrying and handling the warm sweet

or germ stocks. During the cooler months the pest is often found in and about the dust collectors, especially if these are warm or are taking heat from the rollers. It should be taken for granted that returned or secondhand sacks are infested and must be treated before being taken into the mill proper. The moth is too widely distributed to-day to justify a miller in taking chances with these sacks.

METHODS OF CONTROL.

The control measures for the Mediterranean flour moth, and, incidentally, for other mill pests, may be divided into three classes: Preventive, including attention to cleanliness; natural control, dealing with nature's attempt at control by parasites; and artificial control, including destruction of pests by fumigation, heat, and cold.

PREVENTIVE MEASURES.

The need for cleanliness can not be overemphasized. Insects prefer to lay eggs upon and develop in flour and cereals lying in undisturbed darkened situations. Insects are most abundant in such places. The frequent cleaning out and destruction of such material nips in the bud what may become an infestation causing a loss many times greater than the cost of cleaning. Experienced millers know this.

FREQUENT CLEANING.

A large proportion of insect infestation in flour mills is due directly to lack of cleanliness. This does not mean that the product coming from such mills is unclean, but that flour is allowed to accumulate for long periods in various places throughout the machinery and buildings to serve as a rich breeding ground for pests, which multiply rapidly and spread to all parts of the mill. It has already been stated that under ordinary flour-mill conditions during the warmer months, the Mediterranean flour moth requires about nine weeks for each generation. Certain other mill pests require from 5 to 7 weeks to complete their life cycle. It is, therefore, evident that if mills are given a thorough cleaning about every five weeks throughout the summer months, much good will be accomplished in reducing pests, for in destroying the stocks removed from undisturbed or dead spaces, many insects are captured and destroyed also. Labor to brush out and remove accumulation of stocks from elevator boots and flour conveyors, and to destroy them by burning is labor well spent. Going over elevator legs with a spout maul, or the use of elevator and belt brushes (fig. 4), will dislodge much infested material and aid greatly in removing accumulations

GOOD CONSTRUCTION.

If walls and ceilings are smooth and well painted or whitewashed, they are kept clean more easily, and offer no places for flour to lodge or insects to breed. Rough stone or brick walls (fig. 5), or those made of matched boards (fig. 6) offer many hiding and breeding places. Floors should be of concrete. where this is possible, for board floorings offer shelter, unless unusually well constructed. Floors and walls should be so joined that there is no opportunity for accumulations along sides and corners. Well-cemented basements that are light and dry are an aid.

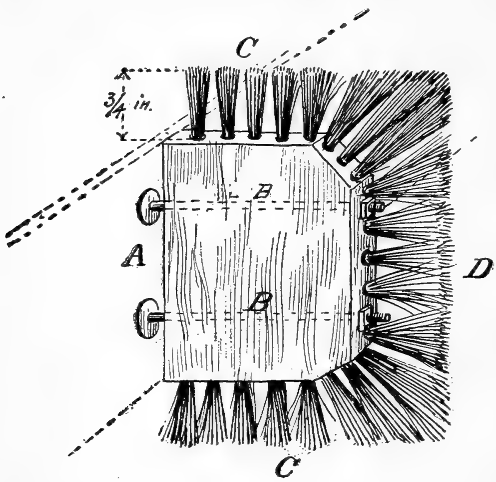

FIG. 4.—Elevator and belt brush for cleaning elevators infested by the Mediterranean flour moth. It is made by taking a piece of 1½-inch board of same dimensions as elevator cups, fastening bristles to three sides. Side A is fastened to elevator belt with flat-headed bolts running through board, as shown at BB, the bolts being ¼ or ⅜ inch. Bristles on sides CC should be ¾-inch long, but those at D should be longer, so that a good brushing to outside of elevator may be secured. Such a brush can be made to fit any elevator. (Chittenden.)

Machinery should be placed high enough to allow frequent and thorough cleaning beneath it. Where practicable the bottoms of flour conveyors should be of metal and rounded, so as to permit the least amount of flour or meal to accumulate along the side and at the ends. The hoppers of the rolls should be constructed of cement and in such manner as to allow no flour to accumulate in inaccessible places.

USE OF LIME.

A liberal use of air-slaked lime in dark corners of damp basements will not only serve as a repellent to insects, but will also tend to destroy some of the objectionable odors and sweeten the air.

CARE OF SACKS AND BAGS.

New sacks and bags should not be stored in packing rooms or in any place where they become dusted with flour or cereal products, for in this flour dust various mill pests can breed and become established ready to attack stocks packed in the sacks. This is an important point often overlooked. Secondhand sacks should never

be taken into the main mill building before they are thoroughly disinfected. It has already been stated that in the majority of cases the spread of moths from mill to mill is traceable directly to the use of untreated secondhand sacks. Such sacks should be stored in a

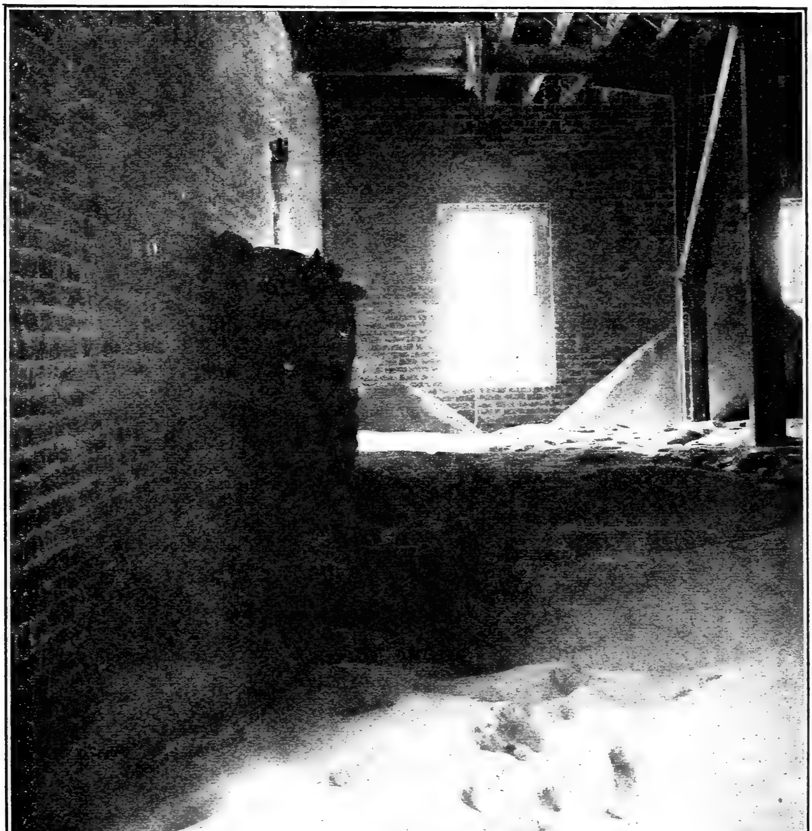

FIG. 5.—View in basement of flour mill. Note accumulations of webbed flour on floor, on bundles of twine, clinging to brick walls, and hanging from overhead beams. The flour in the foreground on floor is badly webbed. Such conditions are not allowed to exist where control measures are put into successful operation.

small, tightly constructed house separated from any part of the mill, and there treated either by heat or fumigation. This may involve extra handling but should become a part of the routine of protection against pests.

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FIG. 6.—Portion of side of very poorly kept flour mill. Note accumulations of flour, much of which is webbed by the flour moth, on side walls, timbers, and ladder. Such neglect breeds trouble.

CLEANLINESS IN WAREHOUSE ROOMS.

Warehouse rooms, as well as the mill proper, should be kept as clean as possible. After each movement of stocks the floor and walls should be cleaned to prevent insects present from holding over to attack a new stock. Neglect of this simple precautionary measure has resulted in a more rapid infestation of warehouse stocks than is generally appreciated.

NATURAL CONTROL BY PARASITES.

In many mills the Mediterranean flour moth is attacked by insect parasites, *Habrobracon hebetor* (Say) and *Omorga frumentaria* (Rond.), but in no case are these of sufficient importance to warrant a miller depending entirely upon them, although at times they may prove a valuable control factor. They are not a dependable factor in any part of the United States. In a successful fight against the flour moth, control by parasites should not be relied upon.

ARTIFICIAL CONTROL MEASURES.

Since the spread of the Mediterranean flour moth from Europe to the milling centers of the United States experimental work has been conducted to determine the most satisfactory methods of control. From the various processes advocated from time to time, such as fumigation with sulphur, carbon disulphid, tobacco fumes, formaldehyde gas, etc., there have finally emerged two control measures that have now proved their value. These are fumigation with hydrocyanic-acid gas and control by heat. Where these can be intelligently and thoroughly applied results can be guaranteed. Heat is unquestionably the cheapest and simplest agent of control now known. Millers have had varying results in attempts to control the moth with freezing temperatures.

HYDROCYANIC-ACID GAS TREATMENT.

Fumigation with hydrocyanic-acid gas, while effective, is a disagreeable method of control. The gas generated is deadly to man, as well as to insects, and precautions must be taken to safeguard the lives of laborers and dwellers in closely associated buildings. It is assumed for the purposes of this bulletin that no milling concern will attempt fumigation with hydrocyanic-acid gas without calling in the services of an expert familiar with the process.[2] It may be added that where it can be used, hydrocyanic-acid gas fumigation is perfectly safe when conducted under the immediate supervision of a

[2] For more complete information regarding the use of this gas, write to the U. S. Department of Agriculture for publications.

properly informed and careful person. Success in the use of hydrocyanic-acid gas is in proportion to the tightness of the mill to be fumigated. Many old loosely constructed mills can not be fumigated successfully, even by an expert fumigator, because they will not hold the gas sufficiently long. In such mills one can not hope to do more than reduce the moth temporarily by any one fumigation. In tight structures two thorough fumigations applied during warm weather within a short time of each other, as discussed on page 27, have been known to exterminate the moth. In rare cases one fumigation has exterminated the moth.

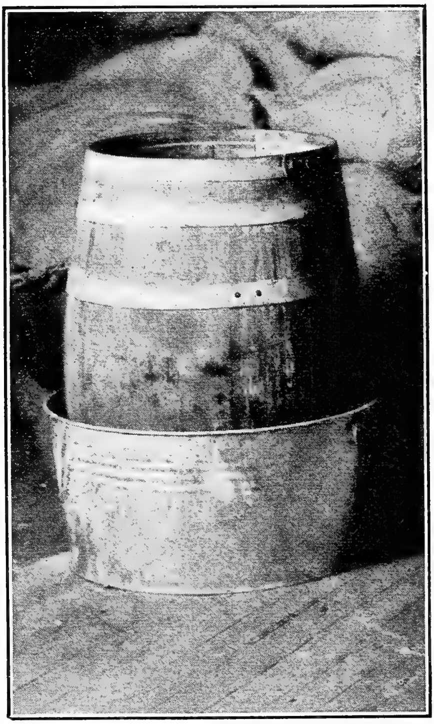

Fig. 7.—Wooden oil barrel, well soaked with water previous to use in fumigation, set in galvanized iron washtub partially filled with water to which have been added several handfuls of sal soda.

Precautionary Measures.

Although it has been stated above that no mill concern should attempt fumigation without the assistance of a chemist, entomologist, or other person well informed regarding the process, attention should be called to several precautions that must be taken to guard against fatalities arising from inexcusable carelessness and ignorance. Very few deaths have occurred as a result of fumigation with hydrocyanic-acid gas as a mill fumigant, and those that have occurred have been due to criminal neglect on the part of those responsible for the fumigation.

Where mills are in buildings well isolated from other buildings, owners need not consider neighbors in their plan for fumigation, but when the fumigation is to be conducted in one of a series of buildings, such as occur in city blocks, owners of property immediately adjoining must be informed of the intention to fumigate and arrangements made with them whereby they will be ready to vacate their stores or offices should the fumes penetrate the intervening walls. The odor of hydrocyanic-acid gas is easily detected, and the person in charge of

fumigation should advise regarding the need to vacate. Persons should be advised not to remain in rooms closely associated with rooms being fumigated if the odor of the gas can be detected. In numerous fumigations persons have remained at their work even when the odor of the gas was very pronounced, and workmen have been known to carry on trucking operations in warehouses where the odor of the residual gas after fumigation was so strong as to give the writer of this bulletin unpleasant feelings. Rooms adjoining those being fumigated should be kept well ventilated, but even then, to remain in them when the odor of the gas can be detected may lead to fatalities directly chargeable to the fumigator. To attempt fumigation without the approval and cooperation of those controlling the occupants of adjoining buildings may lead to fatalities directly chargeable to criminal neglect on the part of the person conducting the fumigation.

Guards should be placed at entrances that can not be closed by means of reliable locks to thoughtless intruders. Only trusted men should be employed to assist in any process of fumigation, and this holds particularly true of the person or persons left on guard. One man, at least, is known to have been killed because he was not informed of the fumigation, returned for night work, and entered through an unlocked door left temporarily unguarded by a sleeping guard. **A genuine responsibility rests upon a person conducting fumigation and he should discharge his duties with all seriousness. He should choose as helpers only the most intelligent and trustworthy employees.**

Preparation of Mill for Fumigation.

Preliminary cleaning.—In fumigating a mill the greatest loss of time is caused by the need for preliminary cleaning; the fumigation can be done between Saturday night and early Monday morning or within any period of 24 hours' duration. The reason for thorough cleaning and destruction of flour and accumulations from various parts of the mill is primarily to leave in the mill at the time of fumigation no masses of stocks which the gas must penetrate to reach all the insects. Hydrocyanic-acid gas, deadly as it is, can not be depended upon to reach and kill all moths, pupæ, eggs, and larvæ if these are buried beneath several inches of well-packed flour, such as often occurs in dead spaces of machines, in floor cracks, basements, etc. The removal and destruction by burning of such accumulations which, as has been stated already, are favored by pests as feeding and breeding places, destroy large numbers of insects, as well as leave the mill in a condition to be fumigated to best advantage.

Make mill as tight as possible.—The mill should be made as tight as possible, so that the gas generated can not escape before it has had a chance to kill the flour moth. Broken windows, ventilators,

and cracks about window frames can be made tight by pasting strips of paper over them. Even an occasional open window and doorways, stairways, and elevator shafts can be fairly well sealed by the use of heavy paper applied in several thicknesses by paper hangers. All

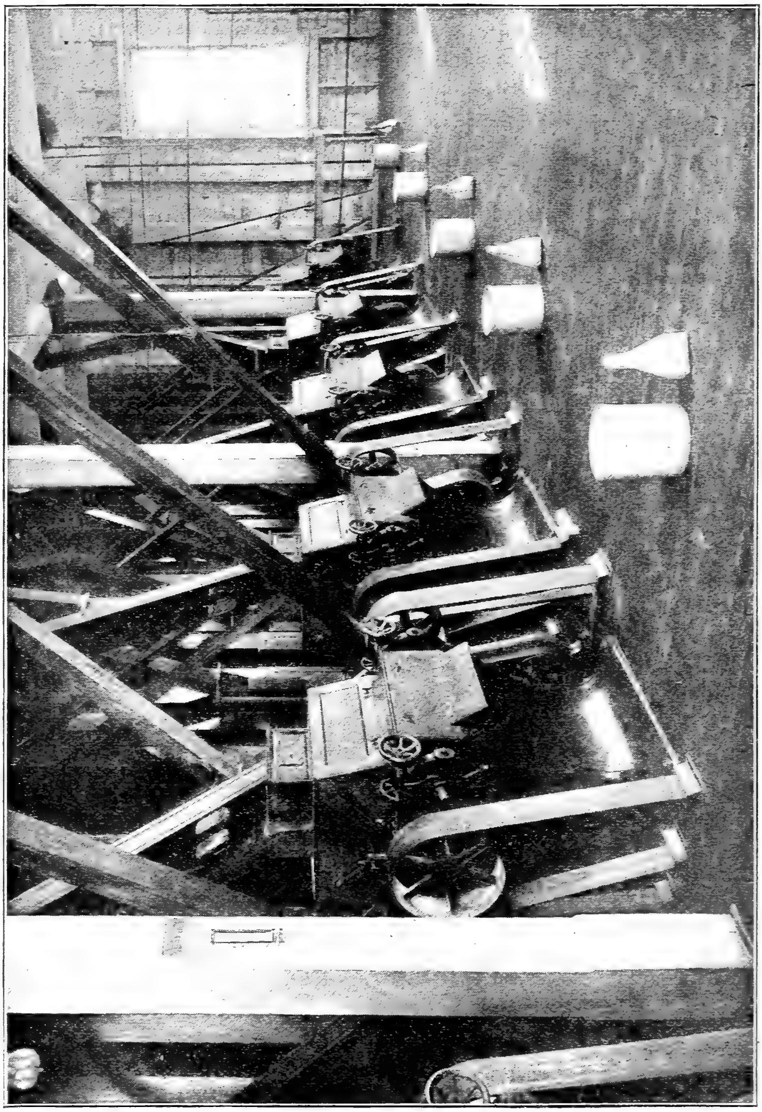

FIG. 8. First floor of a flour mill, showing the proper arrangement of the generators and the bags of cyanid for hydrocyanic-acid gas fumigation where the bags are to be dropped by hand. (Dean.)

such openings must be closed before fumigation is attempted or failure will result. As the gas has a tendency to rise, each floor should be treated as a unit by closing such openings as those formed by elevator shafts, stairways, etc. The small openings through which

belting passes and similar openings in the floor can be sufficiently well closed by crowding pieces of sacking firmly into them.

Chemicals Necessary for Fumigation.

The chemicals necessary for the generation of hydrocyanic-acid gas are potassium or sodium cyanid,[3] sulphuric acid, and water.

Cyanid.—Either potassium cyanid or sodium cyanid can be used in fumigation, but trade conditions have made sodium cyanid more available for use and, as it is just as good and slightly cheaper, it is recommended. For a full discussion of the relative values of potassium and sodium cyanid for fumigating purposes, see Bulletin 90 of the Bureau of Entomology. Sodium cyanid for fumigation purposes should be 96 to 99 per cent guaranteed purity. The volume of gas liberated is in direct proportion to the purity of the cyanid, hence too much stress can not be placed on purchasing high-grade cyanid. Protection can be had by purchasing a cyanid guaranteed under the Federal insecticide act; the analysis on the label should show that the cyanid is at least as pure as follows:

Sodium cyanid (NaCN), 96 to 99 per cent, analysis.

	Per cent.
Cyanogen (CN), not less than	51.3
Sodium (Na), not more than	43.7
Inert substances, not more than	4.0
Chlorids, not more than	1.4

High-grade cyanid can be purchased in tin cans containing 50, 100, or 200 pounds. For ease in handling and preparing doses, it is convenient to purchase brands of cyanid in which the material is divided into lumps weighing approximately 1 ounce each. Cyanid decomposes slowly when exposed to the air, hence such cyanid as remains unused after a fumigation should be protected by being placed in an air-tight receptacle. Where this can not be done, the filling in of the original container with firmly packed sacking will greatly retard decomposition.

Sulphuric acid.—Commercial sulphuric acid (H_2SO_4) 92 to 94 per cent pure (66° Baumé), free from nitric acid, arsenic, lead, and zinc, should be used. It may be made from pyrites or pure brimstone, so long as impurities are eliminated. Acid is usually purchased in iron drums containing 800 to 1,500 and 2,000 pounds, though when used in smaller quantities it can be had in glass carboys of about 100 pounds capacity. Pure acid is colorless and about twice as heavy as water; its specific gravity is 1.83. When stored in iron drums it

[3] Recent developments in liquid hydrocyanic acid indicate that sooner or later its use will replace this long established method of generating gas by the mixing of chemicals in containers.

frequently has a milky white color, especially at the bottom of the drum, due to the presence of sulphate of iron resulting from the

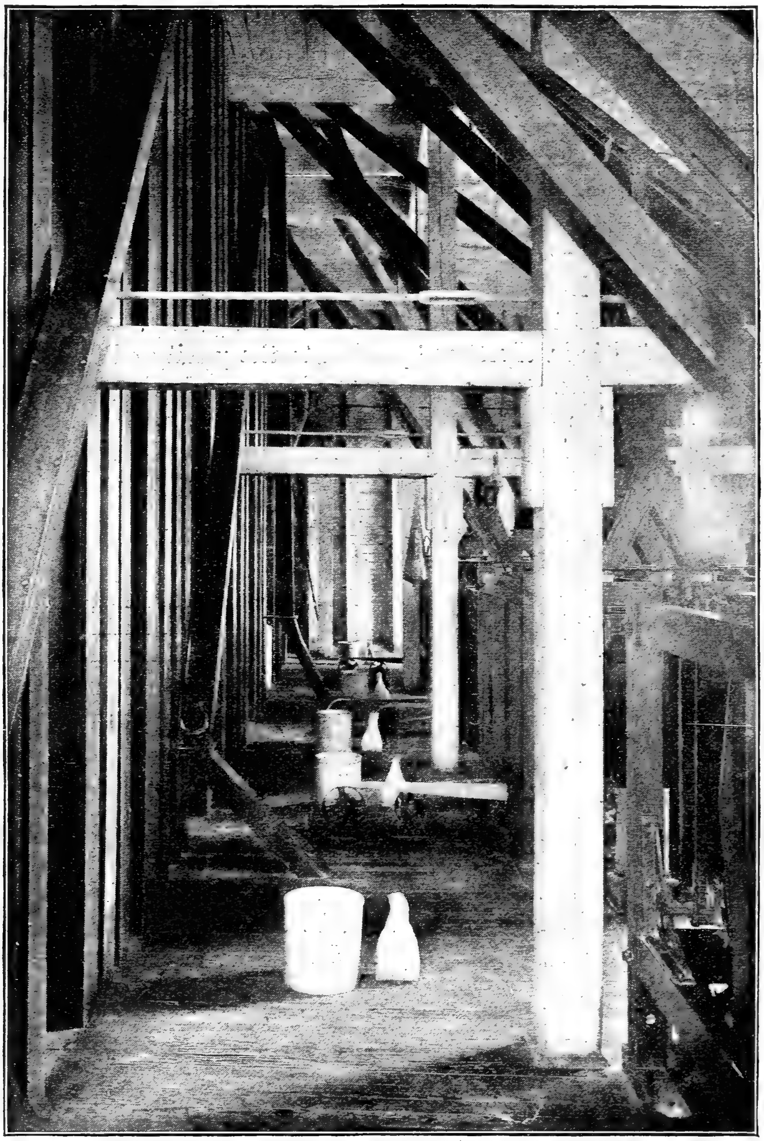

FIG. 9.—Second floor of a flour mill, showing the proper arrangement of the generators and the bags of cyanid for hydrocyanic-acid gas fumigation where the bags are to be dropped by hand. (Dean.)

action of the acid upon iron either before or after the acid is placed in the drum. This sediment does not affect the value of the acid

unless present in excessive quantities. In estimating the amount of acid required it is sometimes convenient to know that $1\frac{1}{2}$ pints of acid

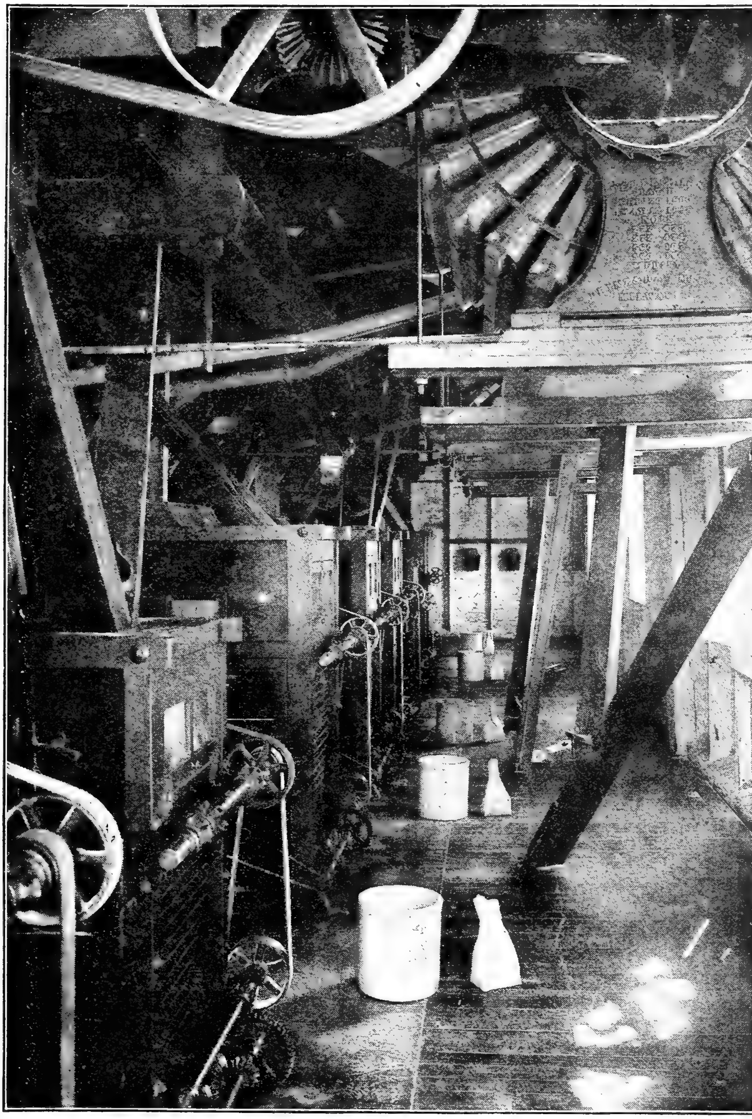

FIG. 10.—Third floor of a flour mill, showing the proper arrangement of the generators and the bags of cyanid for hydrocyanic-acid gas fumigation where the bags are to be dropped by hand. (Dean.)

by liquid measure is required for each pound of cyanid when the following formula is used.

PROPORTION OF CHEMICALS.

Hydrocyanic-acid gas is generated by mixing in proper proportion sodium cyanid, sulphuric acid, and water. These should be combined as follows:

1 ounce, by weight, of sodium cyanid.
1½ ounces, liquid measure, of sulphuric acid.
2 ounces, liquid measure, of water.

This is known as the 1–1½–2 formula. Slightly varying formulas have been recommended, but this 1–1½–2 formula yields good results.

EQUIPMENT FOR GENERATING GAS.

The equipment for generating gas may be very simple and should include the following:

Containers for generating the gas.—For mill fumigation, 4-gallon earthenware stone crocks, well glazed, such as may be purchased at any hardware store, have proved very satisfactory. Four-gallon crocks (see figs. 8 to 14) will receive a charge containing a maximum of 4 pounds of cyanid. Fumigation does not injure them for other purposes provided they are properly cleaned. Where very large spaces are to be fumigated strong water-tight wooden barrels have frequently been used. Untreated oil barrels in good condition have served for several fumigations without marked deterioration, where care is taken to add the acid slowly and to rinse thoroughly after using. A 50-gallon barrel will accommodate with ease a charge of 20 to 30 pounds. Containers holding larger quantities of solution are more difficult to remove and empty than smaller ones, and this is an important item. Good barrels sufficiently small to fit easily into an ordinary galvanized-iron washtub (fig. 7) and receive charges of 15 to 30 pounds of cyanid are very satisfactory when buildings are so arranged that they can be easily removed and emptied. If the tubs are partly filled with water to which have been added several handfuls of ordinary salsoda, there is no danger that the acid will spill out onto the floor during the chemical reaction which produces the gas, and the handles of the tub make it easy for two men to remove the tub and barrel at the same time after fumigation.

Measuring and carrying equipment.—Scales are needed for weighing cyanid. Glass graduates of 16 or 32 ounce capacity should be used for measuring acid and water. One or two gallon granite ware cups and pitchers are very convenient and safe for carrying acid. Ordinary granite ware buckets in good condition can be used very satisfactorily in carrying acid from carboys to generators, though these should be carefully washed immediately after use and not allowed to stand with acid in them. Containers of tin must not be used.

Sacks.—Sacks for holding the individual charges of cyanid are needed. When 4-gallon crocks are used common manila paper sacks, sizes 8 and 10, such as may be had of any grocer, are the best

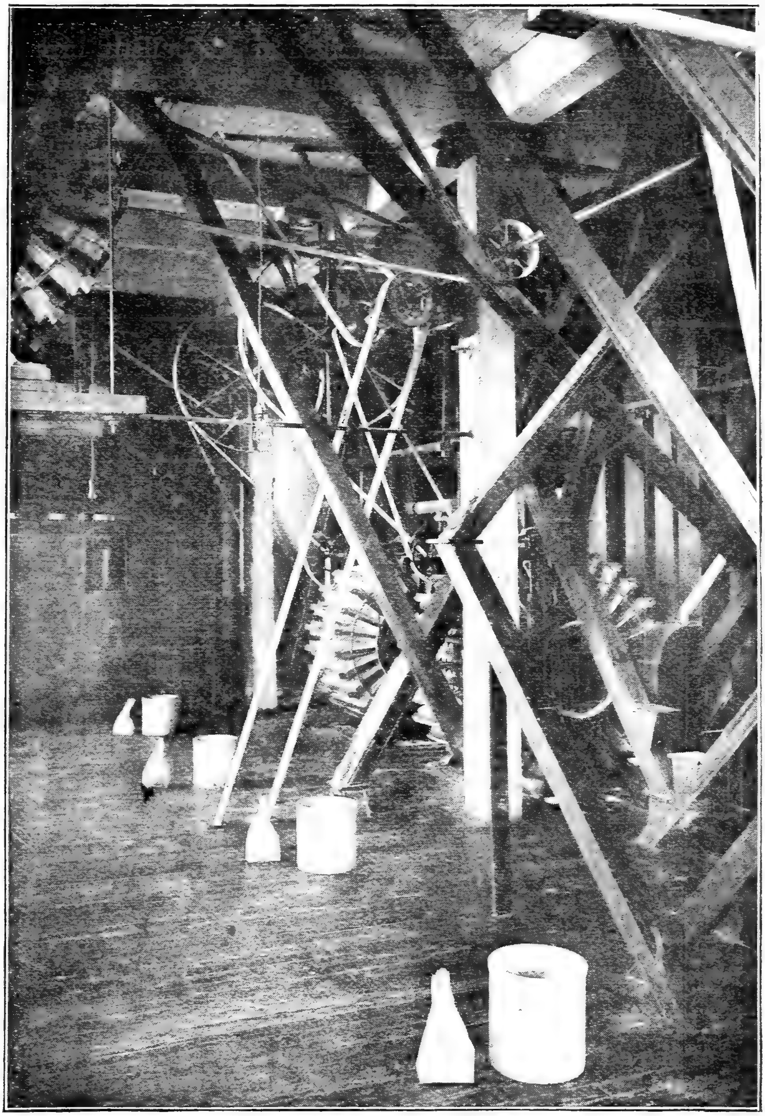

FIG. 11.—Fourth floor of a flour mill, showing the proper arrangement of the generators and the bags of cyanid for hydrocyanic-acid gas fumigation where the bags are to be dropped by hand. (Dean.)

in which to place the cyanid. The cyanid is placed in the smaller sack, after which the smaller sack is slipped within the larger one. Sacks of heavy or heavily glazed paper should not be used, for

they retard the action of the acid upon the cyanid. Where larger doses must be carried old bran sacks may be used for the cyanid.

Protection against burns and charring.—Persons engaged in fumigation according to the method described in this bulletin invariably receive slight injuries to their clothing in the form of acid burns due to spattering and dripping of acid. Only the oldest clothing should be worn. A saturated solution of common washing soda crystals (sodium carbonate) should be at hand ready to apply to hands, face, or floor to neutralize acid spatterings that may occur. When acid is purchased in iron drums a sufficient number of 5 to 10 gallon glass carboys in the usual wooden frames to hold all acid

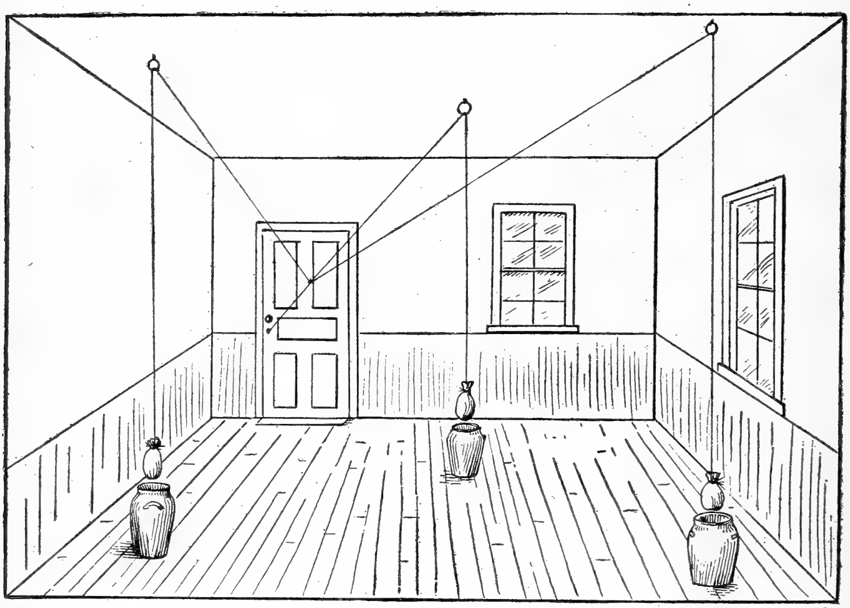

FIG. 12.—Diagram showing "stringing method" used in generating hydrocyanic-acid gas. The number of generators connected with the main cord may vary to fit the need of individual cases. (Chittenden.)

needed for the fumigation, should be provided to hasten the measuring of the acid. To guard against injury to the mill flooring, the acid should be measured outside the mill; or if this work is done within the mill old sacks and sawdust should be used liberally to prevent any acid spilled during the work from damaging the floor.

Provision for ventilating rooms after fumigation.—Care should be taken to provide for the ventilation of rooms or buildings after fumigation. It is dangerous to enter rooms to open windows from within although experienced fumigators often take such risks. Ingenuity can be depended upon to discover a way to open windows, transoms, or skylights from the outside by means of cords or wires.

Estimating Spaces.

After a decision to fumigate has been made, the amount of space to be fumigated must be determined by securing the inside measurements of the length, width, and height of each room. No deductions should be made for machinery, bins, etc.

Amount of Chemicals Needed.

Once the cubic contents have been determined the amount of chemicals needed can be calculated easily. In the treatment of single tight rooms 1 ounce of cyanid is recommended for each 100 cubic feet of space. Where a reasonably tight mill has 4 or 5 floors the following standard, suggested by Dean, should be followed, as the gas is light and has a tendency to concentrate on the upper floors. Use 1 pound of sodium cyanid to each 1,000 cubic feet of space in the basement, to each 1,200 cubic feet of space on the first floor, to each 1,300 cubic feet of space on the second floor, to each 1,500 cubic feet of space on the third floor, and to each 1,600 cubic feet of space on the fourth and fifth floors. When buildings are rather loosely constructed, a larger amount of cyanid will be needed, but no directions can be given that will be as useful in determining the amount necessary to offset the looseness of individual mills as one or two experimental fumigations.

According to the 1–1½–2 formula recommended on page 18, for each 100 pounds (1,600 ounces) by weight of cyanid required there will be needed also 2,400 fluid ounces of sulphuric acid.

Number of Generators Required.

If 4-gallon crocks are used for generating the gas, one crock will be needed for each 4 pounds of cyanid required, or for each 6,400 cubic feet of space, when 1 ounce of cyanid is used to each 100 cubic feet of space. Where larger generators are used, as discussed on page 18, determine the amount of cyanid to be used in each container and use it to divide the total cyanid required for the building or room to secure the number of generators needed. It is always well not to overtax the capacity of a generator.

Placing of Generators.

In placing the generators or jars, care must be taken to have them sufficiently distant from machinery, belting, sacks, walls, etc., so that there may be no danger of injury from spattering during gas generation. The reader is directed to examine carefully figures 8 to 11 for illustrations of how best to arrange generators. In using crocks it is always best to place beneath each crock some old sacking or papers, as not infrequently there is a slight spattering of the floor

close to the crocks during the chemical action which forms the gas. This is particularly true when a maximum charge for any container is used.

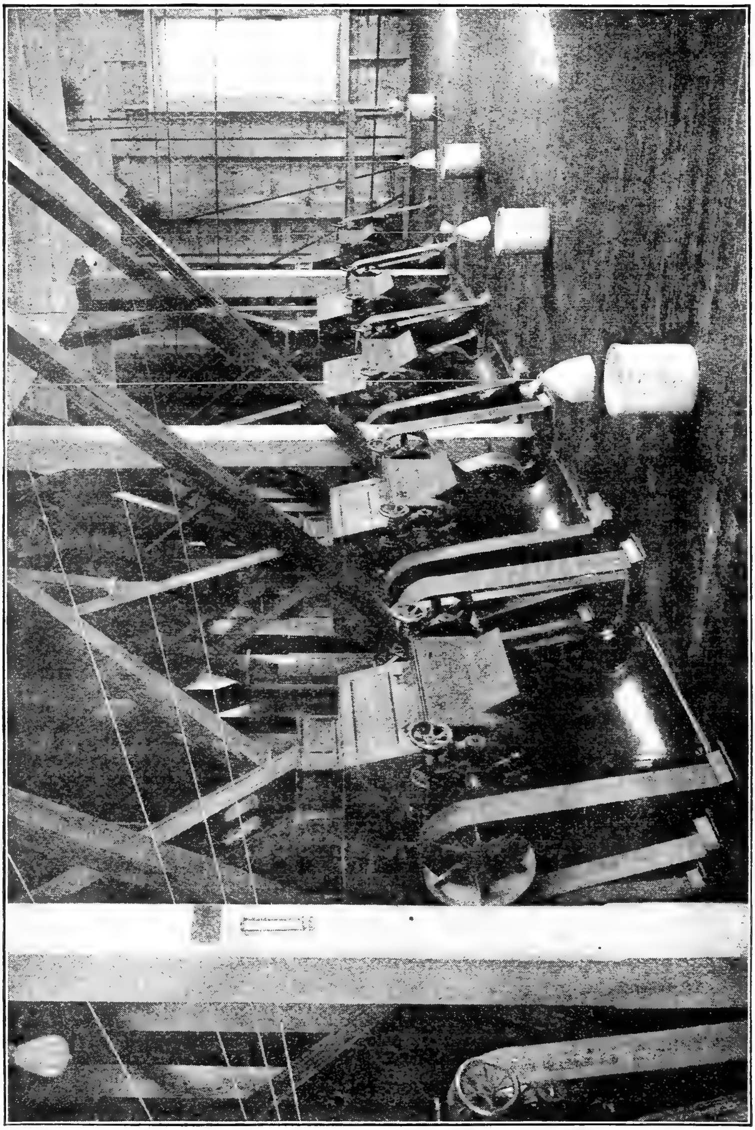

FIG. 13.—First floor of a flour mill, showing the proper arrangement of the generators and the bags of cyanid for hydrocyanic-acid gas fumigation where the string system is to be used. (Dean.)

ORDER OF ASSEMBLING CHEMICALS FOR FINAL GENERATION OF GAS.

Having decided upon the number of generators for each floor and the amount of charge for each, the generators should be well distributed. The proper amount of water should then be measured out

and poured into each container. The acid should always be added to the water and never vice versa. The mixing of water and sulphuric acid generates heat; hence care should be taken to pour the acid slowly into the water to prevent too rapid a rise in temperature, which might cause a cracking of the crocks. As the gas is formed best when the mixture of acid and water is warm, the acid should not be added until just before the fumigation is started. As soon as the acid is poured into the generators the cyanid, which has already been weighed out into proper amounts and placed in sacks, should be distributed, one sack by each generator, as illustrated in figures 8 to 11.

Dropping of the Cyanid.

By this time everything should be in readiness for the generation of the gas. The building has been tightly closed, except for the doors or windows through which those who drop the cyanid will leave the building. Provision has been made for ventilating after fumigation (p. 20), the building has been cleaned (p. 13), made tight (p. 13), and manholes, slide doors, etc., in spouts, elevator legs, etc., have been opened, and all persons have been accounted for, those not assigned to dropping cyanid having left the building. Starting on the top floor, begin dropping the cyanid carefully, though quickly, into the generators, starting at the jars most distant from the exit and working rapidly toward the exit. This requires quick, cool-headed action. If a charge of cyanid is overlooked never go back to drop it; let it go—your safety comes first. When the last charge has been dropped leave the floor, closing the door behind, and repeat the operation on each successive lower floor.

When the person in charge feels that it is not wise to attempt to drop all charges of cyanid by hand because of difficulties in the way of retreat the *stringing method should be employed*. Novices often resort to this method, though experienced fumigators do not, except in difficult situations. Where floors are so crowded with machinery that a hasty exit can not be made, or in dropping charges in the basement where one must run upstairs to the first floor before reaching the exterior the use of the stringing method will eliminate danger. This method consists in passing strong cord through conveniently arranged screw-eyes, each string finally passing from a central point at the exit to and through a screw-eye in the ceiling, so that it will hang directly over the spot where the generator is to be placed. (See figs. 12, 13, and 14, *4*.) The strings should be so arranged that they may all be lowered into the jars by releasing one main string. This may be done by carrying the strings leading to each jar through screw-eyes in the ceiling or wall to one stout cord at the exit, as illustrated in figure 12. After the strings have

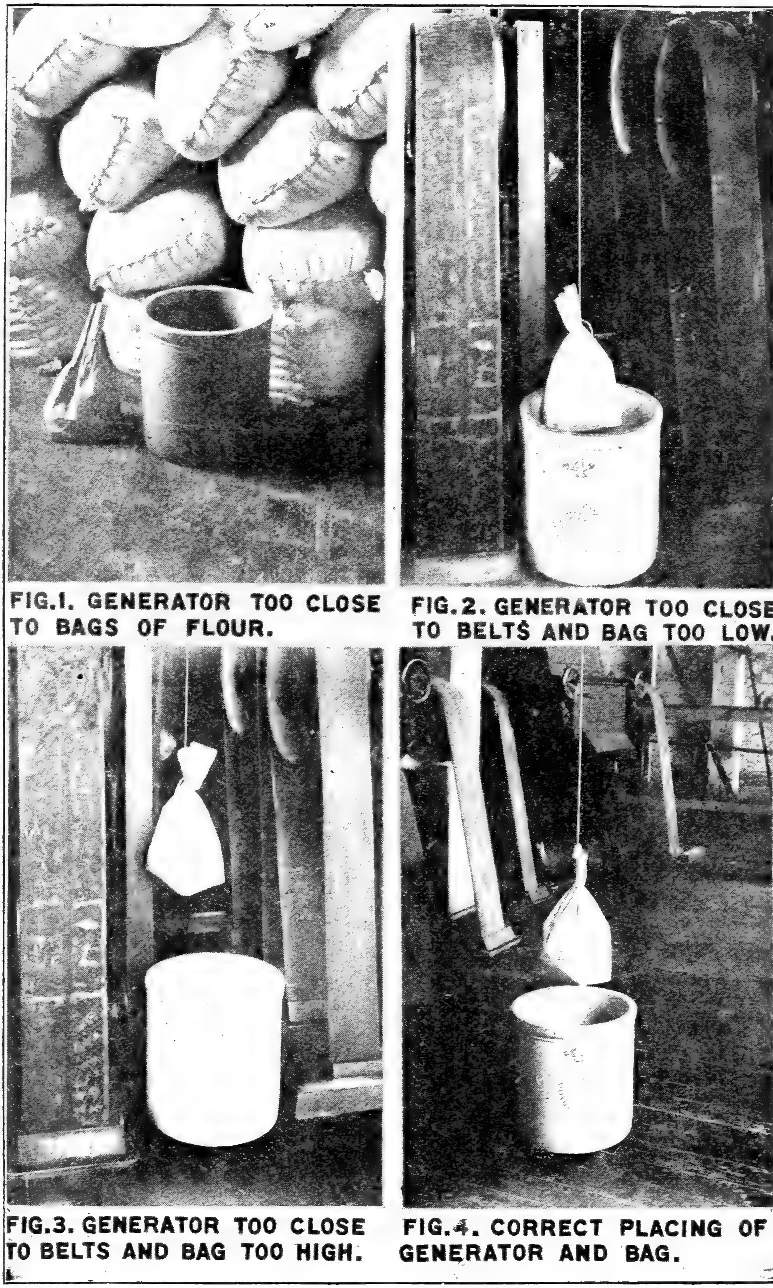

FIG. 14.—The correct and incorrect placing of generators and bags of cyanid for hydrocyanic-acid gas fumigation. (Dean.)

been arranged, the generators should be placed and the water and acid added. Each generator should then be moved at least 2 feet away from where the cyanid will be suspended. Men should then go through the mill, tying firmly the sacks of cyanid to the strings, so that they will hang suspended about 2 or 3 inches above the tops of the generators. This done, the generators are placed beneath the suspended sacks. All persons should then leave the building. One man can now pass from the top to the lower floors lowering the cyanid into the generators by the simple manipulation of the central cord at the exit of each floor. The basement charge should, of course, be lowered last, and preferably by means of a cord running to the outside mill door or to the outside through some slight opening about a window.

Closing Buildings and Guarding Doors.

After the last charge has been set off and the last person has left the building, the door or doors used as exits should be locked. If such doors do not fit tightly, it will pay to paste strips of paper about their edges. Guards should be placed about the building in such a manner as to prevent persons entering the building. Guards should not stand where they can smell any amount of escaping gas. There should be several guards who keep in touch with one another, especially during the first one or two hours after the generation of gas.

Time to Fumigate and Length of Exposure.

Fumigate only during calm weather. During high winds the gas is carried to one side of the room or building and, unless the building is very tight, it is dissipated more quickly. Experiments have proved that insects are not active at temperatures lower than 50° to 60° F. and are not then so easily killed by the gas. Best results follow fumigations when the temperature is 70° F. or above. Everything for fumigation should be in readiness before dark. When possible the best time to fumigate is from Saturday afternoon to Sunday evening or Monday morning. At this time fewer people are about. The buildings should be allowed to remain closed for fumigation not less than 12 to 18 hours, though exposures of from 24 to 36 hours, when the building is tight and time is not an important factor, may effect a better killing of pests.

Ventilation.

Several hours should elapse after a mill has been opened for ventilation before laborers are allowed to enter for regular work. The doors and the windows should be opened from without, according to provision made before fumigation. In opening windows and doors, open first those on the side of the building opposite to the

direction from which the wind is coming. After the preliminary ventilation has been in progress for one or two hours, it is safe for an operator to enter and open all windows and doors, but he should not remain in the building until it has been thoroughly aired. Specific directions as to the length of time for ventilation can not be given to meet all cases. Much depends upon the movement of air currents, the humidity of the air, and the rate of gas leaking from the building during the hours of fumigation. To be absolutely safe, buildings should be ventilated until there is no odor of gas before persons are allowed to resume their work. Men accustomed to fumigate soon acquire from experience knowledge which governs their action in remaining in buildings during the period of ventilation.

Procedure After Ventilation.

After the mill has been ventilated thoroughly an operator should tour the building and make certain that no charge of cyanid was overlooked in the dropping or that no charge failed to be lowered into the generators if the stringing method was used. Any such charges should be removed from the building and placed with the stock of unused cyanid. Laborers should now be sent through the building to remove the generators, dumping their contents into a sewer or into a hole dug in the ground and giving the generators a thorough washing. If the chemical action has been complete, the residue in the jars after fumigation may not be particularly poisonous, yet it is acid, and will burn clothing and skin, and should be handled with care by reliable men. Men should be warned against deliberately inhaling any fumes that may be given off by the residue, either while they are removing the generators or emptying them. Generators that begin to bubble when disturbed should be avoided until the bubbling has ceased. When the residue has been absorbed, after it has been poured in the hole in the ground, the soil should be replaced.

Efficiency of Fumigation.

Experiments prove that in an air-tight chamber hydrocyanic-acid gas will penetrate in killing concentrations to a depth of 3 inches, but in mill fumigation the gas does not penetrate flour and mill products much beyond 1 inch, and often, particularly near the floor, not even that far. Not all mill pests are equally affected by the gas. In a mill infested by the Mediterranean flour moth hydrocyanic-acid gas is a very effective treatment. All stages of the moth, including the egg, if not covered with more than 1 inch of flour, are killed, but upon the several stages of the flour beetles, "bran bugs," and the cadelle the gas treatment is of less value. Many of these pests hide in places

inaccessible to the gas and escape treatment only to restock the mill later and offset the large numbers of their species killed during the fumigation.

Frequency of Fumigation.

Most millers who fumigate with hydrocyanic-acid gas apply the treatment once a year. Certain millers fumigate in the spring, give a second fumigation during midsummer, and a third during early fall. A more effective plan is to give two fumigations in July or August within three or four weeks of each other. Of the different stages of the moth, the egg stage is the most difficult to kill, and a certain number of eggs usually escape the first fumigation. If, then, a second fumigation is applied three to four weeks after the first, it will catch the worms that hatch from the eggs unaffected by the first fumigation, when they are in a stage easily killed by the gas; at that time they have not had an opportunity to develop into adult moths and lay more eggs. Fumigation is advocated only for the warm summer months.

Effects of Hydrocyanic-Acid Gas Upon Flour.

Experiments conducted at the Kansas Agricultural Experiment Station, results of which are published in Bulletin No. 178 of that station, included fumigations of four grades of soft winter-wheat flour, consisting of a patent, a straight, a clear, and a low grade, and of three grades of hard winter wheat flour, consisting of a patent, a straight, and a low grade. Samples were fumigated at the maximum strength recommended for flour-mill fumigation, viz, 1 pound of cyanid to each 1,000 cubic feet of space. Flour was exposed to a temperature of 90° F in a tight chamber kept at constant temperature for a period of 12 hours. Dean, of Kansas, concludes:

> It is only in the careful measurements employed in the test that any difference between the fumigated and the unfumigated flour is apparent at all. The only notable difference appears in the maximum volume of the dough in the test made immediately after fumigation, but not after thirty days. The finished loaf shows no deleterious effect from fumigation in any of the tests.

CONTROL BY HEAT.

It has been stated that fumigation with hydrocyanic-acid gas, effective as it is in controlling the Mediterranean flour moth in mills, does not control so satisfactorily the several stages of the flour beetles (*Tribolium confusum* Duv. and *T. ferrugineum* Fab.), the "bran bug" (*Laemophloeus minutus* Oliv.), the cadelle (*Tenebroides mauritanicus* L.), and the sawtoothed grain beetle (*Silvanus surinamensis* L.) These insects are naturally more resistant to the effect of gas, and secrete themselves in large numbers in cracks and accumu-

lations of fine stocks inacessible to any gas. The flour beetles and the cadelle, the larval stages of which cause much trouble in flour, are in practically every flour mill in the country, except where remedial measures are successfully practiced. Inspection of ports in this country and in Europe through which the flour from many American mills is handled, either for domestic or for foreign trade, indicates that these insects just mentioned, which can not be controlled so satisfactorily by fumigation, are causing serious trouble, and that the large majority of the infestations originate at the mills.

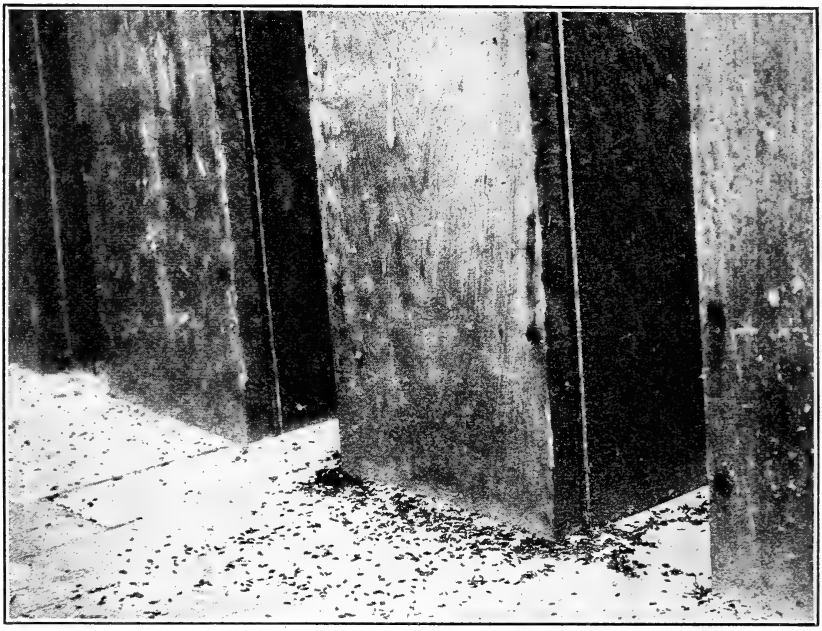

FIG. 15.—Photograph of elevator legs after application of the heat method of control. Note the large number of flour beetles which, on feeling the heat, have crawled out of the cracks of the wooden elevator legs and died upon the mill floor.

The most practical and effective method known to control all classes of mill-infesting insects is the application of high temperatures. (Fig. 15.)

Heat has been recognized as a control agent for many years in this country and in Europe. But its effectiveness as a control measure in flour mills was first demonstrated by professional experimental investigation by Prof. George A. Dean in several Kansas mills during the period 1910–1913.[4] So successful were Dean's demonstrations that the heat method has been tested by the Federal Bureau of Entomology and by several State entomologists with the result that mills in

[4] DEAN, GEORGE A., MILL AND STORED-GRAIN INSECTS. Kans. State Exp. Sta. Bul. 189, p. 139–236, 56 figs., 6 pl., July, 1913.

Kansas, Ohio, Nebraska, Illinois, Indiana, Iowa, southern Canada, Virginia, and elsewhere are equipped for and are using the heat method. The result of all this work is that to-day the heat method is recognized as the most effective, practical, and inexpensive of all treatments, and has the added advantage of being absolutely safe. The greatest expense is the original installation of radiating surface. Yet this expense is offset by the greater cheapness of the heat method as compared with any other effective control measure. Goodwin,[4] an experimenter in Ohio, claimed in 1912 that for a mill of average size, forced to apply remedial measures, the cost of steam piping necessary to obtain killing temperatures was offset within five years by the saving due to the cheapness of the heat method.

Heat Applied Most Effectively in Summer.

It is advised that heat be applied during the summer months in order that the normally high temperatures then obtaining may be turned to the advantage of the miller. It is much easier to raise the temperature of a mill to the killing point when the outdoor temperature is 85° F. or above. It takes less fuel and less radiation surface and saves time. Take advantage of summer heat. Heat only in quiet weather; it is impossible to get uniformly good results during windy weather.

Degree of Heat Necessary.

A temperature of 118° F. to 125° F. in all parts of the mill is sufficient to kill mill pests. To obtain these killing temperatures in the least exposed parts, it is necessary to heat other portions to a still higher temperature unless greater care than usual is taken to distribute radiation surfaces according to the situation. For temperatures secured in various parts of mills heated experimentally with equipments already installed, see data in Tables I to XII.

Use of Steam Heat.

Steam heat is the most satisfactory heat for raising mill temperatures to the killing point. A pressure of 25 to 50 pounds is recommended.

Amount of Radiation Required.

The number of square feet of radiation required to heat a given number of cubic feet of space depends upon the number of doors and windows in a building and upon the general tightness of the structure. Because these factors vary so greatly in mills, a definite recommendation for amount of radiation surface can not be given. The engi-

[4] Goodwin, W. H., flour mill fumigation. Bul. Ohio Agr. Exp. Sta., no. 234, p. 184, January, 1912.

neer of each establishment, aided by one or two experimental heatings, will be able to increase or reduce the radiation surface in various parts of the mill until provision is made for securing sufficiently high temperatures. One square foot of radiation is usually sufficient to heat from 50 to 100 cubic feet of space. A mill with sufficient radiation to heat it during winter to 70° F. without the heat of the running machinery can be heated readily in summer to 120° F. or 125° F. Dean suggests for a five-story building 1 square foot of radiation to each 50, 60, 75, 90, and 110 cubic feet of space for the first, second, third, fourth, and fifth floors, respectively; and in a mill of four floors, 1 square foot of radiation to each 50, 60, 75, and 100 cubic feet of space for the first, second, third, and fourth floors, respectively. The amount of radiation surface per linear foot and the linear feet of pipe per square foot of radiation surface for pipes of varying sizes are as follows:

Size of pipe, in inches.	Radiation surface per linear foot.	Linear feet of pipe per square foot of radiation surface.
1	0.346	2.9
1¼	.434	2.3
1½	.494	2.0
2	.622	1.6
2½	.753	1.3

If steam-pipe is used for radiation the 1¼-inch or 1½-inch size is recommended as most practical.

HEAT DOES NOT INJURE EQUIPMENT.

Heating mills as recommended for the control of mill pests will not injure the mill structure or equipment. In the many heatings on record no injury has occurred to belting or machinery, or, by checking, to elevator legs, woodwork of bolters, and purifiers. Mills have been heated to as high as 150° F. for 30 hours without injury to any part.

Objection made that insurance companies will not permit the heat method of control is without foundation. Mr. William Reed, as secretary of the Mutual Fire Protection Bureau, representing eight of the principal millers' insurance companies, in a notice to all policy holders stated, "We propose to advocate the heating system for effective fumigation against the Mediterranean flour moth, weevil, and all other mill and grain infesting insects."

FLOUR NOT AFFECTED BY HEAT METHOD.

Results of baking tests made of patent hard-wheat flour, a low-grade hard-wheat flour, and a pancake flour have proved conclu-

sively that the heat method, even at several degrees of temperature higher than recommended for mill treatment, has no injurious effect upon the baking qualities of the flour. A low hard-grade wheat flour was subjected to a temperature of 140° F. for nine hours on three successive occasions (the second and third heatings occurring two and six weeks after the first heating), and a pancake flour was subjected to a temperature of 130° F. for 48 hours without injurious results.

Effect of Heating upon Mill Humidity.

Heating to kill mill insects greatly reduces the humidity in the mill. Insects die more quickly in a dry heat than in a moist heat. The relative humidity on the second floor of a mill at 10 a. m., when the heat was turned on, was 93 per cent; by 12 m. it had fallen to 40 per cent, and by 5.30 p. m. to 27 per cent. In a second mill the relative humidity at 6 a. m., when the heat was turned on, was recorded by a hygrograph as 72 per cent; during the first few hours following there was a rapid decrease to less than 40 per cent, and during the afternoon and throughout the night there was a still further decrease to 12 per cent.

Important Points to be Considered in the Successful Heating of a Mill.

1. Steam pipes should be located near floor and arranged to give equal distribution of heat.
2. Provide water trap for drawing off accumulation of water in pipes.
3. Lower floors and floors with heavy machinery should have more radiating surface in proportion to cubic feet of space than upper floors and floors with light machinery.
4. Mill will heat more rapidly with a steam pressure of 25 to 50 pounds.
5. To take advantage of heat in machinery begin heating mill immediately after shutdown.
6. Stairways and elevator shafts should be closed, so as to make separate units of each floor.
7. Thermometers should be placed at different points on each floor that temperatures may be readily ascertained.
8. Time must be taken to reach desired temperatures.
9. A temperature of 118° F. to 125° F. is sufficient for any part of mill.
10. This temperature should be maintained for several hours to allow heat to penetrate all infested parts.
11. Do not attempt to heat on a windy, cold, or rainy day.

12. By beginning the heat process directly after shutting down mill Saturday afternoon and continuing until Sunday night or early Monday, there is no loss in producing hours.

EXPERIMENTAL DATA ON HEAT FUMIGATION.

The following temperatures and results were secured in experimental work by Dean (mills 1 to 4) and by Goodwin[5] (mill 5).

MILL NO. 1.

Brick building; day (July 7–8, 1912) calm, partly cloudy; outdoor maximum temperature 91° F., outdoor minimum temperature 73° F. Heating system, steam pipes along walls, except in space beneath first floor where radiators are used. Steam pressure of about 20 pounds maintained during experiment. Capacity of mills, 600 barrels.

ON FIRST AND SECOND FLOORS.

Location and reading of thermometers.—The thermometers were located on these floors as follows: No. 1, in 2 inches of flour in elevator boot on floor, 8 feet beneath steam pipes; No. 2, hanging in middle of room, 5 feet high, 15 feet from steam pipes; No. 3, in 2 inches of flour in elevator boot on floor, 12 feet from steam pipes; No. 4, hanging in the open, 4 feet high, 15 feet from steam pipes; No. 5, between the rolls in a roll, 11 feet from steam pipes; No. 6, hanging in the open, 6 feet high, near roll machinery.

TABLE I.—*Data showing rise in temperatures on first and second floors.*

Time of day.	First floor: Capacity, 28,728 cubic feet; radiation, 525 square feet.			Second floor: Capacity, 28,728 cubic feet; radiation, 560 square feet.		
	Thermometer—					
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
July 7, 1912:	° F.	° F.	° F.	° F.	° F.	° F.
10.30 a. m.	83	90	86	98	97	99
11.30 a. m.	83	94	88	105	97	106
12.30 p. m.	84	98	91	110	98	111
2.30 p. m.	88	104	96	117	100	118
3.30 p. m.	90	106	100	120	102	121
4.30 p. m.	93	107	102	123	104	123
5.30 p. m.	94	110	103	125	105	125
7 p. m.	95	110	107	127	108	127
8.30 p. m.	97	113	108	129	109	129
9.30 p. m.	98	115	108	130	111	129
July 8, 1912:						
9 a. m.	100	122	116	140	122	140
11 a. m.	106	124	117	142	125	142
12 m.	106	125	118	144	126	144
2 p. m.	106	128	118	144	127	144
4 p. m.	107	129	120	147	129	147
5.30 p. m.	108	129	121	146	131	145

ON THIRD AND FOURTH FLOORS.

Location and reading of thermometers.—Thermometers were located on these floors as follows: No. 1, hanging in the open, 5 feet high, 15 feet from steam

[5] Op. cit.

pipes; No. 2, in flour in a conveyor near floor, 12 feet from steam pipes; No. 3, in flour in conveyor, 6 feet high, 15 feet from steam pipes; No. 4, hanging in the open, 5 feet high, 12 feet from steam pipes; No. 5, in flour, in a conveyor near floor, 12 feet from steam pipes; No. 6, in flour, in a conveyor near floor, 12 feet from steam pipes.

TABLE II.—*Data showing rise in temperatures on third and fourth floors.*

Time of day.	Third floor: Capacity, 31,122 cubic feet; radiation, 460 square feet.			Fourth floor: Capacity, 43,092 cubic feet; radiation, 400 square feet.		
	Thermometer.					
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
July 7, 1912:	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*
10.30 a. m.	95	85	89	96	88	88
11.30 a. m.	100	88	91	100	90	90
12.30 p. m.	105	91	95	105	92	91
2.30 p. m.	114	100	102	114	99	97
3.30 p. m.	116	102	103	116	101	99
4.30 p. m.	119	105	107	118	103	101
5.30 p. m.	122	107	108	119	106	103
7 p. m.	124	111	111	120	109	106
8.30 p. m.	126	113	113	121	111	109
9.30 p. m.	127	114	114	122	112	110
July 8, 1912:						
9 a. m.	133	126	125	127	118	117
11 a. m.	138	127	125	129	119	118
12 m.	139	127	126	132	120	119
2 p. m.	141	128	128	133	121	120
4 p. m.	143	128	131	138	124	122
5.30 p. m.	145	129	131	138	124	122

RESULTS OF HEATING MILL NO. 1.

One hundred per cent of all insects were killed on the second, third, and fourth floors. All insects were killed on the first floor, except those in elevator boots on the floor, where killing temperatures were not secured except directly over the radiators in the space beneath the floor.

MILL NO. 2.

Brick building; day (July 21, 1912) partly cloudy and calm; maximum outdoor temperature 97° F.; minimum outdoor temperature 74° F. Heating system, steam pipes along wall and a few radiators. Steam pressure of about 100 pounds maintained during heating. Capacity of mill, 1,000 barrels.

BASEMENT AND FIRST FLOOR.

Location and reading of thermometers.—No. 1, in flour in an elevator boot resting on floor, 5 feet from steam pipes; No. 2, hanging in the open, 6 feet high, 10 feet from steam pipes; No. 3, in flour in an elevator boot resting on floor, 15 feet from steam pipes; No. 4, in flour in an elevator boot resting on floor, 10 feet from steam pipes; No. 5, hanging in the open, 6 feet high, 15 feet from steam pipes; No. 6, in flour in a roll, 20 feet from steam pipes; No. 7, in flour in a roll in the cleaning room, 5 feet from a radiator.

TABLE III.—*Data showing rise in temperatures in basement and on first floor.*

Time of day.	Basement: Capacity, 33,790 cubic feet; radiation, 1,020 square feet				First floor: Capacity, 40,040 cubic feet; radiation, 780 square feet.		
	Thermometer—						
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.
July 21, 1912:	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*
8 a. m.	96	128	98	98	130	121	97
10 a. m.	97	134	104	98	138	123	100
12 m.	100	136	105	98	140	123	102
2 p. m.	102	136	107	102	140	124	108
4 p. m.	104	38	108	106	142	125	111
6 p. m.	103	140	109	109	143	127	113
8 p. m.	103	143	109	109			
10.30 p. m.	102	145	113	109	146	131	119

SECOND AND THIRD FLOORS.

Location and reading of thermometers.—No. 1, hanging in the open, 6 feet high, 15 feet from steam pipes; No. 2, in flour in bottom of an elevator boot, 15 feet from steam pipes; No. 3, in flour on bolting cloth in a reel, 12 feet from radiation (cleaning room); No. 4, hanging in the open, 5 feet high, 12 feet from steam pipes; No. 5, in flour in a conveyor, 14 feet from steam pipes; No. 6, hanging in the open, 5 feet high, 10 feet from radiator (cleaning room).

TABLE IV.—*Data showing rise in temperature on second and third floors.*

Time of day.	Second floor: Capacity, 43,120 cubic feet; radiation, 800 square feet.			Third floor: Capacity, 43,120 cubic feet; radiation, 900 square feet.		
	Thermometer—					
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*
July 21, 1912:						
8 a. m.	137	112	110	120	108	116
10 a. m.	144	119	113	126	114	121
12 m.	147	122	115	131	116	125
2 p. m.	151	127	121	136	120	130
4 p. m.	153	130	124	138	123	132
6 p. m.	153	128	126	139	124	134
8 p. m.	154	128	128	141	127	136
10.30 p. m.	156	130	129	142	129	138

RESULTS OF HEATING MILL NO. 2.

One hundred per cent of the insects were killed everywhere except in elevator boots resting on the concrete floor in the basement.

MILL NO. 3.

Brick building; day (July 27–28, 1912) calm and partly cloudy; outdoor maximum temperature 105° F.; outdoor minimum temperature 73° F.; heating system, steam pipes along wall; steam pressure of about 100 pounds maintained during heating. Capacity of mill, 1,000 barrels.

BASEMENT, FIRST, AND SECOND FLOORS.

Location and reading of thermometers.—No. 1, hanging in the open, 5 feet high; No. 2, in flour in an elevator boot resting on floor; No. 3, in flour in an elevator boot resting on floor; No. 4, in some bran in a roll, 12 feet from steam pipes; No. 5, hanging in the open, 5 feet high, 10 feet from steam pipes; No. 6, in flour in an elevator boot resting on floor; No. 7, hanging in the open, 5 feet high, 15 feet from steam pipes; No. 8, in flour in a conveyor, 20 feet from steam pipes; No. 9, in 4 inches of flour near floor, 8 feet from steam pipes.

TABLE V.—*Data showing rises in temperatures in basement and on first and second floors.*

Time of day.	Basement: Capacity, 23,199 cubic feet; radiation, 260 square feet.			First floor: Capacity, 29,526 cubic feet; radiation, 210 square feet.			Second floor: Capacity, 27,417 cubic feet; radiation, 168 square feet.		
	Thermometer—								
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.
July 27-28:	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*
9.30 p. m.	113	104	102	110	118	105	117	108	109
11.30 p. m.	112	102	102	113	121	107	120	111	112
July 28:									
6.30 a. m.	109	96	100	116	123	110	126	114	120
7.30 a. m.	110	99	99	118	124	110	126	116	120
9.30 a. m.	118	108	110	120	128	113	130	117	121
11.30 a. m.	122	109	109	122	129	114	131	119	124
12.30 p. m.	122	110	110	123	130	115	132	131	134
2.30 p. m.	124	113	113	124	131	116	133	122	126
4.30 p. m.	128	114	115	126	134	119	136	125	128
5.30 p. m.	129	115	115	127	135	120	137	127	128
7.30 p. m.	130	119	118	130	137	123	138	128	130
9.30 p. m.	130	117	117	130	137	123	138	128	130
11 p. m.	130	118	118						
July 29:									
1 a. m.	134	120	120						
3 a. m.	136	122	122						
4.30 a. m.	136	122	122						

THIRD FLOOR AND DECK.

Location and reading of thermometers.—No. 1, in flour in a conveyor near the floor, 20 feet from steam pipes; No. 2, hanging in the open, 5 feet high, 12 feet from steam pipes; No. 3, in a pile of flour on the floor, 10 feet from steam pipes; No. 4, hanging in the open, 5 feet high; No. 5, in refuse flour on the base of a dust collector near the floor; No. 6, in flour 3 feet from the floor.

TABLE VI.—*Data showing rise in temperatures on third floor and deck.*

Time of day.	Third floor and deck: Capacity, 45,343 cubic feet, including deck; radiation, 326 square feet; radiation, deck, none.					
	Thermometer—					
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
July 27-28:	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
9.30 p. m.	111	120	111	123	113	115
11.30 p. m.	113	122	113	124	115	116
6.30 a. m.	118	128	119	130	120	122
7.30 a. m.	119	130	120	131	122	124
9.30 a. m.	122	132	122	134	126	126
11.30 a. m.	124	136	124	138	127	129
12.30 p. m.	125	137	126	138	128	130
2.30 p. m.	128	139	128	141	133	134
4.30 p. m.	129	141	129	143	133	136
5.30 p. m.	130	142	130	144	134	137
7.30 p. m.	132	142	132	144	136	138
9.30 p. m.	132	141	131	143	136	138

RESULTS OF HEATING MILL NO. 3.

One hundred per cent of insects were killed on the first to deck floors. In the basement 90 per cent were killed; the steam-pipe exhaust opened into a pit beneath the basement floor and this allowed the escaping steam to enter the basement and keep the air moist.

MILL No. 4.

Frame building; day (July 28, 1912) partly cloudy with light breeze; outdoor maximum temperature 95° F.; outdoor minimum temperature 72° F. Heating system, steam pipes along wall, steam pressure of about 80 pounds maintained during heating. Capacity, 1,000 barrels.

FIRST FLOOR.

Location and reading of thermometers.—No. 1, hanging in the open, 5 feet high, 15 feet from steam pipes; No. 2, hanging in the open, 5 feet high, 18 feet from steam pipes; No. 3, resting on a roll in a roller, 12 feet from steam pipe; No. 4, in 2 inches of flour near floor, 5 feet from steam pipes; No. 5, in flour in a conveyor near floor, 20 feet from steam pipes; No. 6, hanging in the open 6 feet high, 20 feet from steam pipes.

TABLE VII.—*Data showing rise in temperature on first floor.*

Time of day.	First floor: Capacity, 34,790 cubic feet; radiation 262 square feet.					
	Thermometers—					
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
July 28, 1912:	° F.	° F.	° F.	° F.	° F.	° F.
8 a. m.	98	96	105	90	....	....
10 a. m.	104	101	106	94	96	110
12 m.	110	106	108	97	104	113
2 p. m.	114	111	109	102	105	117
4 p. m.	118	115	110	107	108	120
6 p. m.	120	116	110	110	110	122
8 p. m.	121	117	112	113	112	123
9 p. m.	121	118	113	114	112	126
9.30 p. m.	121	118	113	114	112	126

SECOND FLOOR.

Location and reading of thermometers.—No. 1, hanging in the open, 5 feet high, 22 feet from steam pipes; No. 2, hanging in the open, 5 feet high, 18 feet from steam pipes; No. 3, in 3 inches of bran near floor, 5 feet from steam pipes; No. 4, in flour in an elevator boot resting on floor, 17 feet from steam pipes; No. 5, in an oven in a laboratory, 5 feet high and 3 feet from steam pipes; No. 6, in flour in an elevator boot resting on floor, 30 feet from steam pipes.

TABLE VIII.—*Data showing rise in temperature on second floor.*

Time of day.	Second floor: Capacity, 38,269 cubic feet; radiation, 190 square feet.					
	Thermometer—					
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
July 28, 1912:	° F.	° F.	° F.	° F.	° F.	° F.
8 a. m.	98	94	93	92	....	....
10 a. m.	102	100	93	94	120	94
12 m.	108	104	95	99	128	97
2 p. m.	114	112	99	104	134	100
4 p. m.	118	115	103	107	139	106
6 p. m.	120	118	106	108	142	106
8 p. m.	122	118	110	110	143	108
9.30 p. m.	122	119	110	112	144	110

THIRD FLOOR.

Location and reading of thermometers.—No. 1, hanging in the open, 5 feet high, 22 feet from steam pipes; No. 2, hanging in the open, 5 feet high, 20 feet from steam pipes; No. 3, in flour in conveyor, 6 feet high, 8 feet from steam pipes; No. 4, in flour in a purifier, 4 feet high, 13 feet from steam pipes; No. 5, in flour in an elevator boot resting on floor, 4 feet from steam pipes; No. 6, in flour in a conveyor near floor, 11 feet from steam pipes.

TABLE IX.—*Data showing rise in temperatures on third floor.*

Time of day.	Third floor: Capacity, 49,375 cubic feet; radiation, 267 square feet.					
	Thermometer—					
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
July 28, 1912:	° F.	° F.	° F.	° F.	° F.	° F.
8 a. m.	98	95	94	96	....	....
10 a. m.	104	101	100	98	96	102
12 m.	109	106	104	104	100	99
2 p. m.	115	112	108	108	104	103
4 p. m.	120	117	112	112	108	108
6 p. m.	124	121	116	116	112	112
8 p. m.	126	123	119	118	114	115
9.30 p. m.	127	124	120	122	116	114

FOURTH FLOOR AND DECK.

Location and reading of thermometers.—No. 1, hanging in the open, 5 feet high, 26 feet from steam pipes; No. 2, hanging in the open, 5 feet high, 28 feet from steam pipes; No. 3, in flour in an elevator boot, 6 inches from floor, 24 feet from steam pipes; No. 4, in flour in a conveyor near floor, 13 feet from steam pipes; No. 5, in flour in a conveyor near floor, 22 feet from steam pipes; No. 6, hanging in the open, 5 feet from floor; No. 7, in flour in a conveyor near floor.

TABLE X.—*Data showing rise in temperatures on fourth floor and deck.*

Time of day.	Fourth floor and deck: Capacity, 69,580 cubic feet, including deck; radiation, 310 square feet; radiation, deck, none.						
	Thermometer—					Deck thermometer—	
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.
July 28, 1912:	° F.	° F.	° F.	° F.	° F.	° F.	° F.
9 a. m.	101	98	93	94	97	104	100
10 a. m.	103	100	95	96	92	106	99
12 m.	110	107	102	100	98	114	112
2 p. m.	116	114	107	102	100	122	113
4 p. m.	122	120	113	106	105	126	118
6 p. m.	126	123	116	110	109	128	123
8 p. m.	126	123	118	115	113	127	125
9.30 p. m.	127	124	118	114	113	127	126

RESULTS OF HEATING MILL NO. 4.

One hundred per cent of the insects were killed on the third, fourth, and deck floors, 95 to 100 per cent were killed on the second, and 90 to 95 per cent were killed on the first floor.

Mill No. 5.

Frame structure, not tightly constructed and with many small openings where lap-siding boards had sprung apart or warped. There are also small openings about doors. Building too loosely constructed for satisfactory fumigation with gas. Day (July 10–11, 1911) calm except for slight breeze blowing from southwest after 9 a. m. July 11, which somewhat affected temperatures on that side of building. Mill equipped with radiators for heating by steam during winter. Outdoor maximum temperature 95° F. No mention made of steam pressure or minimum outdoor temperature.

FIRST AND SECOND FLOORS.

Location and reading of thermometers.—No. 1, near airshaft; No. 2, set 5 inches deep in flour; No. 3, in boot of elevator; No. 4, three feet from floor; No. 5, on inside of outer wall; No. 6, near floor in elevator leg; No. 7, on support post; No. 8, on outside wall; No. 9, in a roll.

Table XI.—*Data showing rise in temperatures on first and second floors.*

Time of day.	First floor.					Second floor.			
	Thermometer—								
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 1.	No. 2.	No. 3.	No. 4.
	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
7.30 p. m.	90	86	100	102	95	107	102	101	107
9.30 p. m.	94	91	102	124	101	120	115	109	119
11.30 p. m.	95	95	106	127	103	122	117	116	122
6 a. m.	96	103	108	131	108	128	124	118	129
8 a. m.	99	104	112	134	111	130	127	120	131
10 a. m.	104	107	113	141	115	135	132	125	137
12 m.	106	109	114	141	116	137	133	126	137
2 p. m.	106	110	115	141	116	137	134	124	138
3 p. m.	107	111	116	141	118				

THIRD FLOOR AND DECK.

Location and reading of thermometers.—No. 1, in conveyor, in 3 inches of flour; No. 2, in elevator leg; No. 3, near outside wall; No. 4, in bolter; No. 5, on a post on the deck built on third floor.

Tabe XII.—*Data showing rise in temperatures on third floor and deck.*

Time of day.	Thermometer—				
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
	° F.	° F.	° F.	° F.	° F.
7.30 p. m.	93	104	102	102	104
9.30 p. m.	104	113	113	116	113
11.30 p. m.	107	118	116	121	116
6 a. m.	118	125	125	129	129
8 a. m.	119	129	129	133	137
10 a. m.	122	134	138	138	140
12 m.	124	135	136	139	142
2 p. m.	127	136	136	139	142

RESULTS OF HEATING MILL NO. 5.

All insects were killed on the second and third floors. Dead beetles and larvæ could be found beneath 3 inches of flour. All insects were killed on the first floor except near air shaft (thermometer No. 1) and those buried 5 inches in flour (thermometer No. 2).

CONTROL BY FREEZING.

If an infested mill is so equipped that it can be opened to low outdoor temperatures without injury to equipment, freezing is an inexpensive and valuable remedy for the flour moth. Turning off all heat and opening the mill to a temperature of zero or lower for from 3 to 10 nights continuously, or at intervals, has often proved effective in destroying the moth in its different stages. Mills in the northern United States and in Canada, where temperatures of 20 to 30 degrees below zero (Fahrenheit) are often experienced, have used this method of control with good results. Mills located farther south where freezing temperatures do not run so low or prevail continuously for any length of time have had little or no benefit from attempts to utilize cold weather.

CONTROL BY SMUDGES.

Control by means of smudges in the form of sulphur or tobacco fumes, etc., is depended upon rather extensively in many mills to reduce flour-moth injury. With smudges one can only expect to reduce the flour moth temporarily by killing the adult moths and certain of the immature stages. The fumes generated are not strong enough to kill as do hydrocyanic-acid gas fumigation and high temperatures. In rambling, loosely constructed buildings, where control by heat and hydrocyanic-acid gas is not practical, smudges, coupled with constant cleaning, have their value. The moth miller or adult is the most easily killed of the different stages of the flour moth and is the form killed in largest proportions by smudges. Since each female moth is the potential parent of several hundred larvæ, one can appreciate the value of the persistent use of smudges. The chief drawback to dependence upon smudges is that they never completely exterminate the moth. Smudges, to accomplish satisfactory results, must be applied frequently, and are therefore costly in the long run. One thorough application of heat rids a mill of the flour moth for long periods if provision is made against reinfestation from without. Flying moths may be found as soon as one day after the application of a smudge.

CONCLUSION.

Control of insect pests in flour and cereal mills has become a very important feature of food conservation and of mill construction and operation. Losses caused by mill insects to mill owners and the ad-

vantages of modern mill construction are working hand in hand to bring about a constant change for the better. Putting into practice methods of control advocated in this bulletin will make it possible for milling concerns to place upon the market a product reasonably free from infestation. When insect sanitation is conscientiously applied, millers can state that blame often heaped upon them by brokers, retail grocers, and the public at large is due to one or more of several known conditions connected with warehousing and transportation, for the miller is in no way responsible.

There are a number of serious insect pests of flour mills. The long-established pests in American mills do not interfere noticeably with operation of mill machinery. With the spread from Europe to the United States of the Mediterranean flour moth (p. 2–5), millers were forced to consider insect sanitation. The danger in the flour moth, sometimes called the "gray plague of flour mills," does not lie so much in food values actually consumed as in the enormous quantities of silken threads spun by its larvæ in and about mill machinery. This webbing habit causes the flour in passing through the machinery to form in ever-increasing clumps or webbed masses, which sooner or later choke or clog the machinery, and necessitates extensive mill shutdowns for cleaning and application of control measures.

Experimental and practical demonstration work has proved the dependability of methods of control under certain conditions. These are fumigation with hydrocyanic-acid gas and the use of heat. Control by freezing (p. 39) is less satisfactory. Smudges, as compared with fumigation with hydrocyanic-acid gas or the application of high temperatures, have only a temporary value. Preventive measures, including cleanliness, are of the greatest value in reducing losses due to insects. Dependence upon natural control by parasites is not advocated. The heat method is recognized as the most effective, practical, and inexpensive of all treatments and has the added advantage of being absolutely safe. Where remedial measures must be applied in mills of moderate size, it has been estimated that the heat method is enough cheaper to pay in five years for the cost of the installation of enough radiation surface properly to heat the mill.

Neither fumigation with hydrocyanic-acid gas nor the use of high temperatures, as recommended for mill-insect sanitation, injures the mill building or equipment or affects the baking qualities of flour.

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